Stanford researchers calculate the mathematics of terror

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George Habash, a militant and former secretary-general of the Popular Front for the Liberation of Palestine, once characterized terrorism as a "thinking man's game." Using mathematics, researchers at Stanford University's Center for International Security and Cooperation (CISAC) have made fighting terrorism a thinking man's game as well.

CISAC affiliate Lawrence M. Wein of the Graduate School of Business and CISAC Science Fellow Jonathan D. Farley are both applying mathematical models to homeland security problems, such as preventing a nuclear detonation in a major U.S. city and determining whether terrorist cells have likely been disrupted.

Wein, who teaches operations classes about different business processes used to deliver goods and services, has focused his research on bioterrorism and border issues. He has performed, he says, the first mathematical analyses of hypothetical botulism poisoning, anthrax outbreaks and smallpox infections.

"One overriding theme of my work is that all these homeland security problems are operations problems," said Wein, the Paul E. Holden Professor of Management Science. "Just as McDonald's needs to get hamburgers out in a rapid and defect-free manner, so too does the government have to get vaccines and antibiotics out and test the borders for nuclear weapons or terrorists in a rapid and defect-free manner."

In collaboration with Stephen Flynn of the Council on Foreign Relations, a nonpartisan research center, Wein recently has conducted research to improve security at U.S. borders and ports. Port security has received significant attention recently owing to the furor over Dubai Ports World's bid to manage six terminals at major U.S. harbors. The aim of Wein and Flynn's work is to prevent terrorists from bringing into the country a nuclear weapon—be it an atomic bomb or a so-called "dirty bomb," or conventional explosive packed with radioactive waste.

"Of all the problems I've studied, this is the most important because the worst-case terrorist scenario is a nuclear weapon going off in a major U.S. city and also it is the one the government has dropped the ball on the most," Wein said. "They have done a very poor job."

Instead of using the existing approach, where U.S. Customs actively inspects a minority of containers based on information from a specialized tracking system designed to identify suspicious containers, Wein and Flynn have recommended the government use a multi-layer, passive screening system for every container entering the country. Under their system, Customs would photograph a shipping container's exterior, screen for radioactive material and collect gamma-ray images of the container's contents. If terrorists shielded a bomb with a heavy metal such as lead to hide it from radiation detectors, gamma-ray imaging would allow inspectors to see the shielding and flag the container for inspection. Wein and Flynn believe this whole process would cost about $7 per container.

"Right now about maybe 6 percent of the containers are deemed suspicious and they will go through some testing and the other 94 percent of the containers just waltz right into the country without an inspector laying an eye on them," Wein said. "What we're proposing to do is 100 percent passive testing."

Wein's earlier work addressed a different threat: bioterrorism. In 2005, Wein revealed the nation's milk supply was vulnerable—a terrorist could potentially poison 100,000 gallons of milk by sneaking a few grams of botulinum into a milk tanker. Although the government and dairy industry have collaborated to intensify the heat pasteurization formula for milk, Wein is still pushing for additional botulinum testing, which he says would cost less than 1 percent of the cost of milk.

Wein also has used math to study smallpox outbreaks, the U.S. fingerprint identification system and U.S.-Mexico border security issues. Wein's congressional testimony on the fingerprint identification system in 2004 led to a switch from a two-finger system to a 10-finger system. His 2003 research on anthrax attacks resulted in a Washington, D.C., pilot program to use the U.S. Postal Service to distribute antibiotics throughout the capital after an outbreak. Seattle is now testing a similar program.

"In Washington, D.C., now, if there is a large-scale anthrax attack, postal workers will be the first to get their Cipro and, on a voluntary basis, they will go door-to-door distributing antibiotics," Wein said.

He said the common thread throughout his research is queuing theory, or the mathematical study of waiting lines, but he also draws upon mathematical epidemiology for his smallpox studies; air dispersion models for the anthrax model; supply chain management for the milk study; probability theory for the fingerprint identification system; and models for nuclear transport and detection for his work with containers.

From tainted lactose to lattice structures

While Wein is working on improving the government's counterterrorism systems, Jonathan Farley is working to figure out when terrorist organizations have been effectively disrupted. His mathematical model is designed to help law enforcement decide how to act once they have captured or killed a terrorist or a number of terrorists in a cell.

A professor at the University of the West Indies who will chair the Department of Mathematics and Computer Science there next year, Farley is on a one-year science fellowship at CISAC. In 2003, he co-founded Phoenix Mathematical Systems Modeling Inc., a company that develops mathematical solutions to homeland security problems.

He is using lattice theory—a branch of mathematics that deals with ordered sets—to determine the probability a terrorist cell has been disrupted once some of its members have been captured or killed.

"Law enforcement has to make decisions about what resources they should allocate to target different cells," Farley said. "The model should provide them with a more rational basis for allocating their scarce resources. … It will inform you when you're making decisions about how much time and effort and how much money you're going to spend going after a particular cell."

While at Stanford, Farley hopes to unearth the perfect structure, mathematically speaking, for a terrorist cell—or in other words, a cell structure that is most resistant to the loss of members.

"If it's possible to determine the structure of an ideal terrorist cell, you can focus on a much smaller number of possibilities, because it makes more sense to assume the adversary is going to be smart rather than stupid," Farley said.

Farley has suggested it is possible Al-Qaida and other terrorist organizations already may have figured out the perfect structure for a terror cell by trial and error.

"I don't expect Osama bin Laden to be reading lattice theory in his caves in Afghanistan," said Farley. "But if it follows from the mathematics, perhaps heuristically, the terrorists will have come to the same conclusion—that this is the best way to structure a terrorist cell."

Although Farley acknowledges his model is not a panacea for terrorism, he hopes it will help reduce guesswork that might be involved in pursuing terrorists.

"It's not that I think mathematics can solve all of these problems," Farley said. "Because it can't. But it's better to use rational means to make decisions rather than guesswork."

Source: Stanford University, by John B. Stafford

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